UNIVERSITY OF JOHANNESBURG

PROGRAM	:	NATIONAL DIPLOMA *CHEMICAL ENGINEERING*
SUBJECT	:	**THERMODYNAMICS APPLIED 3111**
CODE	:	**ACT 3111**
DATE	:	SUMMER EXAMINATION 2015 20 NOVEMBER 2015
DURATION	:	(SESSION 1) 08:30 - 11:30
WEIGHT	:	40: 60
TOTAL MARKS	:	100

EXAMINER	:	MRS TP MASHIFANA
MODERATOR	:	DR H RUTTO
NUMBER OF PAGES	:	9 PAGES INCLUDING ANNEXURES

INSTRUCTIONS

: **QUESTION PAPERS MUST BE HANDED IN**
: CALCULATORS ARE ALLOWED
: NO COMPUTERS ALLOWED
: NUMBER AND ANSWER ALL QUESTIONS IN AN ORDER
: UNIVERSITY EXAM RULES APPLY

Question 1 **[40]**

1. The Carnot cycle is the most efficient ideal theoretical cycle. There are four steps that make up a ***Carnot cycle***,

1.1. Name the four processes (4)
1.2. Show a T-s diagram for the cycle (3)
1.3. Show a P-v diagram for the cycle (3)

2. An oil engine takes in air at 1.5 bar, 30 °C and the maximum cycle pressure is 85 bar. The compression ratio is 16/1.

2.1. Draw a P-v diagram for the process (5)
2.2. Calculate the air standard thermal efficiency based on the dual-combustion cycle. (25)

Assume that heat added at constant volume is equal to heat added at constant pressure

Question 2 **[15]**

A gas turbine has an overall pressure of 5 bar and a maximum cycle efficiency at 550 °C. The turbine drives the compressor and an electric generator, the mechanical efficiency of the drive is 97 %. The ambient temperature is 20 °C and air enters the compressor at a rate of 15 kg/s; the isentropic efficiencies of the compressor and turbine are 80 and 85 % respectively. Neglecting changes in kinetic energy, the mass flow rate of fuel and all pressure losses, calculate:

2.1. The power output (5)
2.2. The cycle efficiency (5)
2.3. The work ratio (5)

Question 3 **[30]**

A compressor in the power turbine is driven by the HP turbine and the LP turbine drives a separate power shaft. Inlet temperature and pressure are 17 °C and 1.01 bar respectively and the pressure ratio is 8/1. The isentropic efficiencies of the compressor, the HP and LP turbines are 0.8, 0.85 and 0.83 respectively. The maximum temperature is 650 °C. Cp = 1.005 kJ/kgK and γ = 1.4 for the compression process, and Cp = 1.15 kJ/kgK and γ = 1.33 for the expansion process. Calculate:

3.1. The pressure and temperature of the gas entering the power turbine
3.2. Net power developed by the power turbine per kg/s of mass
3.3. The work ratio.
3.4. The thermal efficiency of a gas turbine unit.

Question 4 **[15]**

A converge diverged nozzle expands air at 6.89 bar and 427 °C into a space at 1 bar. The throat area of the nozzle is 650 mm^2 and the exit area is 975 mm^2. The exit velocity is found to be 680 m/s where the inlet velocity is negligible. Assuming that friction in the converged portion is negligible, calculate:

4.1. The mass flow through the nozzle, stating whether the nozzle is under expanding or over expanding;
4.2. The nozzle efficiency
4.3. The coefficient of velocity

TOTAL MARKS = 100
FULL MARKS = 100

Formula Sheet

1. Carnot cycle: $\eta = \frac{W_{net}}{Q_1} = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_2}{T_1}$

2. Constant pressure cycle: $\dot{m} = \frac{\dot{W}_{net}}{W_{net}}$

   Work ratio W: $W = 1 - \frac{T_1}{T_3}\left(\frac{P_2}{P_1}\right)^{(\gamma-1)/\gamma}$

   $Gross\ work\ output = work\ output\ of\ HP\ turbine + work\ output\ of\ LP\ turbine$

   Adiabatic change in temperature $T_{i+1} = T_i\left(\frac{P_{i+1}}{P_i}\right)^{(\gamma-1)/\gamma}$

3. Otto cycle thermal efficiency: $\eta = 1 - \frac{1}{\left(\frac{V_1}{V_2}\right)^{\gamma-1}}$

4. Diesel cycle thermal efficiency: $\eta = 1 - \left(\frac{1}{V_1/V_2}\right)^{\gamma-1}\left\{\frac{(V_3/V_2)^{\gamma}-1}{\gamma[(V_3/V_2)-1]}\right\}$

5. Dual-combustion cycle: $\eta = 1 - \frac{C_v(T_5-T_1)}{C_v(T_3-T_2)+C_p(T_4-T_3)}$

6. Mean effective pressure: $-W_{net} = P_m(V_1 - V_2)$

7. Stirling and Ericsson cycles: $\eta_{Stirling} = \eta_{Ericsson} = \eta_{Carnot} = 1 - \frac{T_2}{T_1}$

8. Rankine cycle pump work input: $W = v_i(P_{i+1} - P_i)$

   Expansion process $Isentropic\ efficiency = \frac{actual\ work}{isentropic\ work}$

   Compression process $Isentropic\ efficiency = \frac{isentropic\ work}{actual\ work}$

9. For steam turbines: $\Delta C_w = C_{wi} + C_{we} = C_{re}\cos\beta_e + C_{ri}\cos\beta_i$

   Velocity coefficient : $k = \frac{C_{re}}{C_{ri}}$

   Diagram efficiency: $\eta_d = \frac{2C_b\Delta C_w}{C_{ai}^2}$

   Stage efficiency: $\eta_s = \frac{C_b\Delta C_w}{H_o - H_i}$

   Nozzle efficiency: $\eta_n = \frac{C_{ai}^2}{2(H_o - H_i)}$

   Driving force: $F_D = \dot{m}\Delta C_w$

   Power output: $\dot{W}_{output} = \dot{m}C_b\Delta C_w$

   End (Axial) thrust: $Axial\ thrust = \dot{m}\Delta C_f$

   where $\Delta C_f = C_{fi} - C_{fe} = C_{ri}\sin\beta_i - C_{re}\sin\beta_e$

   and $\Delta C_w = C_{wi} + C_{we} = C_{re}\cos\beta_e + C_{ri}\cos\beta_i$

10. For Nozzles: Energy balance: $H_1 + \frac{C_1^2}{2} = H_2 + \frac{C_2^2}{2}$

    Critical pressure: $\frac{P_c}{P_1} = \left(\frac{2}{\gamma+1}\right)^{\gamma/(\gamma-1)}$

    Critical temperature: $\frac{T_c}{T_1} = \left(\frac{P_c}{P_1}\right)^{(\gamma-1)/\gamma}$

    Critical specific volume: $v_c = \frac{(R/M)T_c}{P_c}$

    Critical velocity: $C_c = \sqrt{\frac{\gamma R T_c}{M}} = \sqrt{2(H_1 - H_c)} = \sqrt{2C_p(T_1 - T_c)}$

Exit specific volume: $v_2 = \frac{(R/M)T_2}{P_2}$

Exit velocity: $C_2 = \sqrt{2(H_1 - H_2)}$

Mass flowrate per unit area: $\frac{\dot{m}}{A_2} = \frac{C_2}{v_2}$

Nozzle efficiency: $Nozzle\ efficiency = \frac{H_1 - H_2}{H_1 - H_{2s}} = \frac{C_p(T_1 - T_2)}{C_p(T_1 - T_{2s})} = \frac{T_1 - T_2}{T_1 - T_{2s}}$

Velocity coefficient: $Velocity\ coefficient = \frac{C_2}{C_{2s}}$

Coefficient of discharge: $Coefficient\ of\ discharge = \frac{\dot{m}}{\dot{m}_s}$

For dry saturated steam $\gamma = 1.135$ & for superheated steam $\gamma = 1.3$

11. Refrigeration: Engine efficiency: $\eta_{carnot} = \frac{W_{net\ carnot\ engine}}{Q_1} = 1 - \frac{T_2}{T_1}$

Coefficient of Performance: $COP_{carnot} = \frac{Q_{1\ refrigerator}}{W_{refrigerator\ input}} = \frac{T_2}{T_1 - T_2}$

Table F.I Saturated Steam, SI Units

V = SPECIFIC VOLUME $cm^3\ g^{-1}$
U = SPECIFIC INTERNAL ENERGY kJ kg
H = SPECIFIC ENTHALPY kJ kg
S = SPECIFIC ENTROPY $kJ\ kg^{-1}\ K^{-1}$

			SPECIFIC VOLUME V			INTERNAL ENERGY U			ENTHALPY H			ENTROPY S		
	T K	P kPa	sat. liq.	evap.	sat. vap.	sat. liq.	evap.	sat. vap.	sat. liq.	evap.	sat. vap.	sat. liq.	evap.	sat. vap.
0	273.15	0.611	1.000	206300.	206300.	−0.04	2375.7	2375.6	−0.04	2501.7	2501.6	0.0000	9.1578	9.1578
0.01	**273.16**	**0.611**	**1.000**	**206200.**	**206200.**	**0.00**	**2375.6**	**2375.6**	**0.00**	**2501.6**	**2501.6**	**0.0000**	**9.1575**	**9.1575**
1	274.15	0.657	1.000	192600.	192600.	4.17	2372.7	2376.9	4.17	2499.2	2503.4	0.0153	9.1158	9.1311
2	275.15	0.705	1.000	179900.	179900.	8.39	2369.9	2378.3	8.39	2496.8	2505.2	0.0306	9.0741	9.1047
3	276.15	0.757	1.000	168200.	168200.	12.60	2367.1	2379.7	12.60	2494.5	2507.1	0.0459	9.0326	9.0785
4	277.15	0.813	1.000	157300.	157300.	16.80	2364.3	2381.1	16.80	2492.1	2508.9	0.0611	8.9915	9.0526
5	278.15	0.872	1.000	147200.	147200.	21.01	2361.4	2382.4	21.01	2489.7	2510.7	0.0762	8.9507	9.0269
6	279.15	0.935	1.000	137800.	137800.	25.21	2358.6	2383.8	25.21	2487.4	2512.6	0.0913	8.9102	9.0014
7	280.15	1.001	1.000	129100.	129100.	29.41	2355.8	2385.2	29.41	2485.0	2514.4	0.1063	8.8699	8.9762
8	281.15	1.072	1.000	121000.	121000.	33.60	2353.0	2386.6	33.60	2482.6	2516.2	0.1213	8.8300	8.9513
9	282.15	1.147	1.000	113400.	113400.	37.80	2350.1	2387.9	37.80	2480.3	2518.1	0.1362	8.7903	8.9265
10	283.15	1.227	1.000	106400.	106400.	41.99	2347.3	2389.3	41.99	2477.9	2519.9	0.1510	8.7510	8.9020
11	284.15	1.312	1.000	99910.	99910.	46.18	2344.5	2390.7	46.19	2475.5	2521.7	0.1658	8.7119	8.8776
12	285.15	1.401	1.000	93830.	93840.	50.38	2341.7	2392.1	50.38	2473.2	2523.6	0.1805	8.6731	8.8536
13	286.15	1.497	1.001	88180.	88180.	54.56	2338.9	2393.4	54.57	2470.8	2525.4	0.1952	8.6345	8.8297
14	287.15	1.597	1.001	82900.	82900.	58.75	2336.1	2394.8	58.75	2468.5	2527.2	0.2098	8.5963	8.8060
15	288.15	1.704	1.001	77980.	77980.	62.94	2333.2	2396.2	62.94	2466.1	2529.1	0.2243	8.5582	8.7826
16	289.15	1.817	1.001	73380.	73380.	67.12	2330.4	2397.6	67.13	2463.8	2530.9	0.2388	8.5205	8.7593
17	290.15	1.936	1.001	69090.	69090.	71.31	2327.6	2398.9	71.31	2461.4	2532.7	0.2533	8.4830	8.7363
18	291.15	2.062	1.001	65090.	65090.	75.49	2324.8	2400.3	75.50	2459.0	2534.5	0.2677	8.4458	8.7135
19	292.15	2.196	1.002	61340.	61340.	79.68	2322.0	2401.7	79.68	2456.7	2536.4	0.2820	8.4088	8.6908
20	293.15	2.337	1.002	57840.	57840.	83.86	2319.2	2403.0	83.86	2454.3	2538.2	0.2963	8.3721	8.6684
21	294.15	2.485	1.002	54560.	54560.	88.04	2316.4	2404.4	88.04	2452.0	2540.0	0.3105	8.3356	8.6462
22	295.15	2.642	1.002	51490.	51490.	92.22	2313.6	2405.8	92.23	2449.6	2541.8	0.3247	8.2994	8.6241
23	296.15	2.808	1.002	48620.	48620.	96.40	2310.7	2407.1	96.41	2447.2	2543.6	0.3389	8.2634	8.6023
24	297.15	2.982	1.003	45920.	45930.	100.6	2307.9	2408.5	100.6	2444.9	2545.5	0.3530	8.2277	8.5806
25	298.15	3.166	1.003	43400.	43400.	104.8	2305.1	2409.9	104.8	2442.5	2547.3	0.3670	8.1922	8.5592
26	299.15	3.360	1.003	41030.	41030.	108.9	2302.3	2411.2	108.9	2440.2	2549.1	0.3810	8.1569	8.5379
27	300.15	3.564	1.003	38810.	38810.	113.1	2299.5	2412.6	113.1	2437.8	2550.9	0.3949	8.1218	8.5168
28	301.15	3.778	1.004	36730.	36730.	117.3	2296.7	2414.0	117.3	2435.4	2552.7	0.4088	8.0870	8.4959
29	302.15	4.004	1.004	34770.	34770.	121.5	2293.8	2415.3	121.5	2433.1	2554.5	0.4227	8.0524	8.4751

30	303.15	4.241	1.004	32930.	32930.	125.7	2291.0	2416.7	125.7	2430.7	2556.4	0.4365	8.0180	8.4546
31	304.15	4.491	1.005	31200.	31200.	129.8	2288.2	2418.0	129.8	2428.3	2558.2	0.4503	7.9839	8.4342
32	305.15	4.753	1.005	29570.	29570.	134.0	2285.4	2419.4	134.0	2425.9	2560.0	0.4640	7.9500	8.4140
33	306.15	5.029	1.005	28040.	28040.	138.2	2282.6	2420.8	138.2	2423.6	2561.8	0.4777	7.9163	8.3939
34	307.15	5.318	1.006	26600.	26600.	142.4	2279.7	2422.1	142.4	2421.2	2563.6	0.4913	7.8828	8.3740
35	308.15	5.622	1.006	25240.	25240.	146.6	2276.9	2423.5	146.6	2418.8	2565.4	0.5049	7.8495	8.3543
36	309.15	5.940	1.006	23970.	23970.	150.7	2274.1	2424.8	150.7	2416.4	2567.2	0.5184	7.8164	8.3348
37	310.15	6.274	1.007	22760.	22760.	154.9	2271.3	2426.2	154.9	2414.1	2569.0	0.5319	7.7835	8.3154
38	311.15	6.624	1.007	21630.	21630.	159.1	2268.4	2427.5	159.1	2411.7	2570.8	0.5453	7.7509	8.2962
39	312.15	6.991	1.007	20560.	20560.	163.3	2265.6	2428.9	163.3	2409.3	2572.6	0.5588	7.7184	8.2772
40	313.15	7.375	1.008	19550.	19550.	167.4	2262.8	2430.2	167.5	2406.9	2574.4	0.5721	7.6861	8.2583
41	314.15	7.777	1.008	18590.	18590.	171.6	2259.9	2431.6	171.6	2404.5	2576.2	0.5854	7.6541	8.2395
42	315.15	8.198	1.009	17690.	17690.	175.8	2257.1	2432.9	175.8	2402.1	2577.9	0.5987	7.6222	8.2209
43	316.15	8.639	1.009	16840.	16840.	180.0	2254.3	2434.2	180.0	2399.7	2579.7	0.6120	7.5905	8.2025
44	317.15	9.100	1.009	16040.	16040.	184.2	2251.4	2435.6	184.2	2397.3	2581.5	0.6252	7.5590	8.1842
45	318.15	9.582	1.010	15280.	15280.	188.3	2248.6	2436.9	188.4	2394.9	2583.3	0.6383	7.5277	8.1661
46	319.15	10.09	1.010	14560.	14560.	192.5	2245.7	2438.3	192.5	2392.5	2585.1	0.6514	7.4966	8.1481
47	320.15	10.61	1.011	13880.	13880.	196.7	2242.9	2439.6	196.7	2390.1	2586.9	0.6645	7.4657	8.1302
48	321.15	11.16	1.011	13230.	13230.	200.9	2240.0	2440.9	200.9	2387.7	2588.6	0.6776	7.4350	8.1125
49	322.15	11.74	1.012	12620.	12620.	205.1	2237.2	2442.3	205.1	2385.3	2590.4	0.6906	7.4044	8.0950
50	323.15	12.34	1.012	12040.	12050.	209.2	2234.3	2443.6	209.3	2382.9	2592.2	0.7035	7.3741	8.0776
51	324.15	12.96	1.013	11500.	11500.	213.4	2231.5	2444.9	213.4	2380.5	2593.9	0.7164	7.3439	8.0603
52	325.15	13.61	1.013	10980.	10980.	217.6	2228.6	2446.2	217.6	2378.1	2595.7	0.7293	7.3138	8.0432
53	326.15	14.29	1.014	10490.	10490.	221.8	2225.8	2447.6	221.8	2375.7	2597.5	0.7422	7.2840	8.0262
54	327.15	15.00	1.014	10020.	10020.	226.0	2222.9	2448.9	226.0	2373.2	2599.2	0.7550	7.2543	8.0093
55	328.15	15.74	1.015	9577.9	9578.9	230.2	2220.0	2450.2	230.2	2370.8	2601.0	0.7677	7.2248	7.9925
56	329.15	16.51	1.015	9157.7	9158.7	234.3	2217.2	2451.5	234.4	2368.4	2602.7	0.7804	7.1955	7.9759
57	330.15	17.31	1.016	8758.7	8759.8	238.5	2214.3	2452.8	238.5	2365.9	2604.5	0.7931	7.1663	7.9595
58	331.15	18.15	1.016	8379.8	8380.8	242.7	2211.4	2454.1	242.7	2363.5	2606.2	0.8058	7.1373	7.9431
59	332.15	19.02	1.017	8019.7	8020.8	246.9	2208.6	2455.4	246.9	2361.1	2608.0	0.8184	7.1085	7.9269
60	333.15	19.92	1.017	7677.5	7678.5	251.1	2205.7	2456.8	251.1	2358.6	2609.7	0.8310	7.0798	7.9108
61	334.15	20.86	1.018	7352.1	7353.2	255.3	2202.8	2458.1	255.3	2356.2	2611.4	0.8435	7.0513	7.8948
62	335.15	21.84	1.018	7042.7	7043.7	259.4	2199.9	2459.4	259.5	2353.7	2613.2	0.8560	7.0230	7.8790
63	336.15	22.86	1.019	6748.2	6749.3	263.6	2197.0	2460.7	263.6	2351.3	2614.9	0.8685	6.9948	7.8633
64	337.15	23.91	1.019	6468.0	6469.0	267.8	2194.1	2462.0	267.8	2348.8	2616.6	0.8809	6.9667	7.8477
65	338.15	25.01	1.020	6201.3	6202.3	272.0	2191.2	2463.2	272.0	2346.3	2618.4	0.8933	6.9388	7.8322
66	339.15	26.15	1.020	5947.2	5948.2	276.2	2188.3	2464.5	276.2	2343.9	2620.1	0.9057	6.9111	7.8168
67	340.15	27.33	1.021	5705.2	5706.2	280.4	2185.4	2465.8	280.4	2341.4	2621.8	0.9180	6.8835	7.8015
68	341.15	28.56	1.022	5474.6	5475.6	284.6	2182.5	2467.1	284.6	2338.9	2623.5	0.9303	6.8561	7.7864
69	342.15	29.84	1.022	5254.8	5255.8	288.8	2179.6	2468.4	288.8	2336.4	2625.2	0.9426	6.8288	7.7714
70	343.15	31.16	1.023	5045.2	5046.3	292.9	2176.7	2469.7	293.0	2334.0	2626.9	0.9548	6.8017	7.7565
71	344.15	32.53	1.023	4845.4	4846.4	297.1	2173.8	2470.9	297.2	2331.5	2628.6	0.9670	6.7747	7.7417
72	345.15	33.96	1.024	4654.7	4655.7	301.3	2170.9	2472.2	301.4	2329.0	2630.3	0.9792	6.7478	7.7270
73	346.15	35.43	1.025	4472.7	4473.7	305.5	2168.0	2473.5	305.5	2326.5	2632.0	0.9913	6.7211	7.7124
74	347.15	36.96	1.025	4299.0	4300.0	309.7	2165.1	2474.8	309.7	2324.0	2633.7	1.0034	6.6945	7.6979

Table F.2 Superheated Steam, SI Units

P/kPa T^{sat}/K(t^{sat}/°C)		sat. liq.	sat. vap.	348.15 (75)	373.15 (100)	398.15 (125)	423.15 (150)	448.15 (175)	473.15 (200)	498.15 (225)	523.15 (250)
				TEMPERATURE: T kelvins (TEMPERATURE: t°C)							
1	V	1.000	129200.	160640.	172180.	183720.	195270.	206810.	218350.	229890.	241430.
280.13(6.98)	U	29.334	2385.2	2480.8	2516.4	2552.3	2588.5	2624.9	2661.7	2698.8	2736.3
	H	29.335	2514.4	2641.5	2688.6	2736.0	2783.7	2831.7	2880.1	2928.7	2977.7
	S	0.1060	8.9767	9.3828	9.5136	9.6365	9.7527	9.8629	9.9679	10.0681	10.1641
10	V	1.010	14670.	16030.	17190.	18350.	19510.	20660.	21820.	22980.	24130.
318.98(45.83)	U	191.822	2438.0	2479.7	2515.6	2551.6	2588.0	2624.5	2661.4	2698.6	2736.1
	H	191.832	2584.8	2640.0	2687.5	2735.2	2783.1	2831.2	2879.6	2928.4	2977.4
	S	0.6493	8.1511	8.3168	8.4486	8.5722	8.6888	8.7994	8.9045	9.0049	9.1010
20	V	1.017	7649.8	8000.0	8584.7	9167.1	9748.0	10320.	10900.	11480.	12060.
333.24(60.09)	U	251.432	2456.9	2478.4	2514.6	2550.9	2587.4	2624.1	2661.0	2698.3	2735.8
	H	251.453	2609.9	2638.4	2686.3	2734.2	2782.3	2830.6	2879.2	2928.0	2977.1
	S	0.8321	7.9094	7.9933	8.1261	8.2504	8.3676	8.4785	8.5839	8.6844	8.7806
30	V	1.022	5229.3	5322.0	5714.4	6104.6	6493.2	6880.8	7267.5	7653.8	8039.7
342.27(69.12)	U	289.271	2468.6	2477.1	2513.6	2550.2	2586.8	2623.6	2660.7	2698.0	2735.6
	H	289.302	2625.4	2636.8	2685.1	2733.3	2781.6	2830.0	2878.7	2927.6	2976.8
	S	0.9441	7.7695	7.8024	7.9363	8.0614	8.1791	8.2903	8.3960	8.4967	8.5930
40	V	1.027	3993.4	....	4279.2	4573.3	4865.8	5157.2	5447.8	5738.0	6027.7
349.04(75.89)	U	317.609	2477.1	....	2512.6	2549.4	2586.2	2623.2	2660.3	2697.7	2735.4
	H	317.650	2636.9	....	2683.8	2732.3	2780.9	2829.5	2878.2	2927.2	2976.5
	S	1.0261	7.6709	....	7.8009	7.9268	8.0450	8.1566	8.2624	8.3633	8.4598
50	V	1.030	3240.2	....	3418.1	3654.5	3889.3	4123.0	4356.0	4588.5	4820.5
354.50(81.35)	U	340.513	2484.0	....	2511.7	2548.6	2585.6	2622.7	2659.9	2697.4	2735.1
	H	340.564	2646.0	....	2682.6	2731.4	2780.1	2828.9	2877.7	2926.8	2976.1
	S	1.0912	7.5947	....	7.6953	7.8219	7.9406	8.0526	8.1587	8.2598	8.3564
75	V	1.037	2216.9	....	2269.8	2429.4	2587.3	2744.2	2900.2	3055.8	3210.9
364.94(91.79)	U	384.374	2496.7	....	2509.2	2546.7	2584.2	2621.6	2659.0	2696.7	2734.5
	H	384.451	2663.0	....	2679.4	2728.9	2778.2	2827.4	2876.6	2925.8	2975.3
	S	1.2131	7.4570	....	7.5014	7.6300	7.7500	7.8629	7.9697	8.0712	8.1681
100	V	1.043	1693.7	....	1695.5	1816.7	1936.3	2054.7	2172.3	2289.4	2406.1
372.78(99.63)	U	417.406	2506.1	....	2506.6	2544.8	2582.7	2620.4	2658.1	2695.9	2733.9
	H	417.511	2675.4	....	2676.2	2726.5	2776.3	2825.9	2875.4	2924.9	2974.5
	S	1.3027	7.3598	....	7.3618	7.4923	7.6137	7.7275	7.8349	7.9369	8.0342

	V	1.044	1673.0	....	1673.0	1792.7	1910.7	2027.7	2143.8	2259.3	2374.5
101.325	U	418.959	2506.5	....	2506.5	2544.7	2582.6	2620.4	2658.1	2695.9	2733.9
373.15(100.00)	H	419.064	2676.0	....	2676.0	2726.4	2776.2	2825.8	2875.3	2924.8	2974.5
	S	1.3069	7.3554	....	7.3554	7.4860	7.6075	7.7213	7.8288	7.9308	8.0280
	V	1.049	1374.6	....	....	1449.1	1545.6	1641.0	1735.6	1829.6	1923.2
125	U	444.224	2513.4	....	....	2542.9	2581.2	2619.3	2657.2	2695.2	2733.3
379.14(105.99)	H	444.356	2685.2	....	....	2724.0	2774.4	2824.4	2874.2	2923.9	2973.7
	S	1.3740	7.2847	....	....	7.3844	7.5072	7.6219	7.7300	7.8324	7.9300
	V	1.053	1159.0	....	....	1204.0	1285.2	1365.2	1444.4	1523.0	1601.3
150	U	466.968	2519.5	....	....	2540.9	2579.7	2618.1	2656.3	2694.4	2732.7
384.52(111.37)	H	467.126	2693.4	....	....	2721.5	2772.5	2822.9	2872.9	2922.9	2972.9
	S	1.4336	7.2234	....	....	7.2953	7.4194	7.5352	7.6439	7.7468	7.8447
	V	1.057	1003.34	....	....	1028.8	1099.1	1168.2	1236.4	1304.1	1371.3
175	U	486.815	2524.7	....	....	2538.9	2578.2	2616.9	2655.3	2693.7	2732.1
389.21(116.06)	H	487.000	2700.3	....	....	2719.0	2770.5	2821.3	2871.7	2921.9	2972.0
	S	1.4849	7.1716	....	....	7.2191	7.3447	7.4614	7.5708	7.6741	7.7724
	V	1.061	885.44	....	....	897.47	959.54	1020.4	1080.4	1139.8	1198.9
200	U	504.489	2529.2	....	....	2536.9	2576.6	2615.7	2654.4	2692.9	2731.4
393.38(120.23)	H	504.701	2706.3	....	....	2716.4	2768.5	2819.8	2870.5	2920.9	2971.2
	S	1.5301	7.1268	....	....	7.1523	7.2794	7.3971	7.5072	7.6110	7.7096
	V	1.064	792.97	....	....	795.25	850.97	905.44	959.06	1012.1	1064.7
225	U	520.465	2533.2	....	....	2534.8	2575.1	2614.5	2653.5	2692.2	2730.8
397.14(123.99)	H	520.705	2711.6	....	....	2713.8	2766.5	2818.2	2869.3	2919.9	2970.4
	S	1.5705	7.0873	....	....	7.0928	7.2213	7.3400	7.4508	7.5551	7.6540
	V	1.068	718.44	....	....	....	764.09	813.47	861.98	909.91	957.41
250	U	535.077	2536.8	....	....	....	2573.5	2613.3	2652.5	2691.4	2730.2
400.58(127.43)	H	535.343	2716.4	....	....	....	2764.5	2816.7	2868.0	2918.9	2969.6
	S	1.6071	7.0520	....	....	....	7.1689	7.2886	7.4001	7.5050	7.6042
	V	1.071	657.04	....	....	....	693.00	738.21	782.55	826.29	869.61
275	U	548.564	2540.0	....	....	....	2571.9	2612.1	2651.6	2690.7	2729.6
403.75(130.60)	H	548.858	2720.7	....	....	....	2762.5	2815.1	2866.8	2917.9	2968.7
	S	1.6407	7.0201	....	....	....	7.1211	7.2419	7.3541	7.4594	7.5590
	V	1.073	605.56	....	....	....	633.74	675.49	716.35	756.60	796.44
300	U	561.107	2543.0	....	....	....	2570.3	2610.8	2650.6	2689.9	2729.0
406.69(133.54)	H	561.429	2724.7	....	....	....	2760.4	2813.5	2865.5	2916.9	2967.9
	S	1.6716	6.9909	....	....	....	7.0771	7.1990	7.3119	7.4177	7.5176